July 25, 1961 F. W. SCHREMP 2,993,542

DIFFUSION APPARATUS

Filed March 31, 1958 4 Sheets-Sheet 1

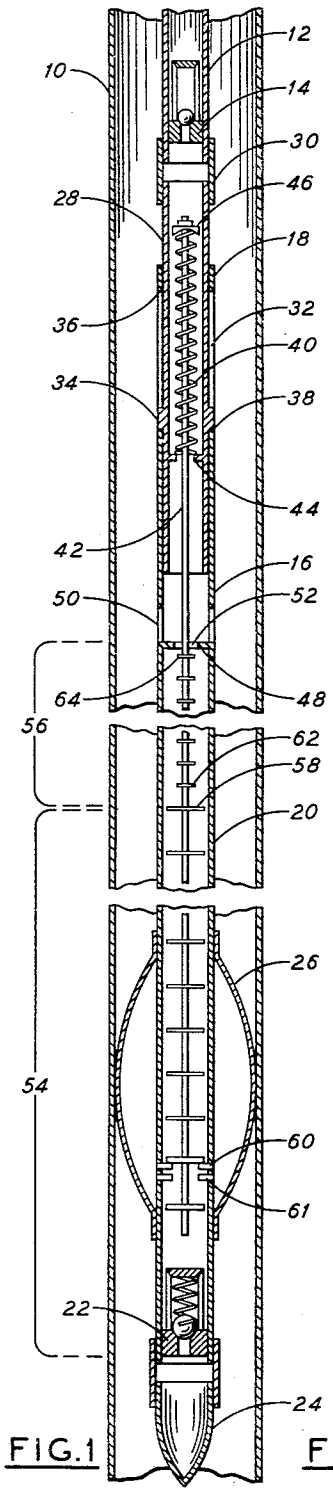


FIG. 1

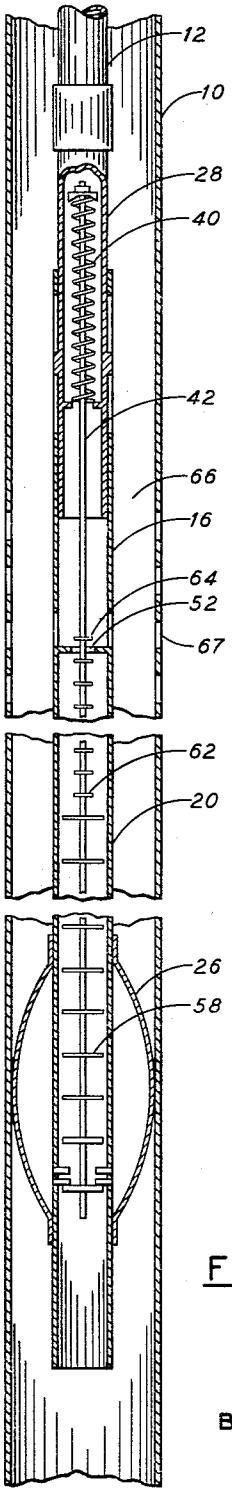


FIG. 7

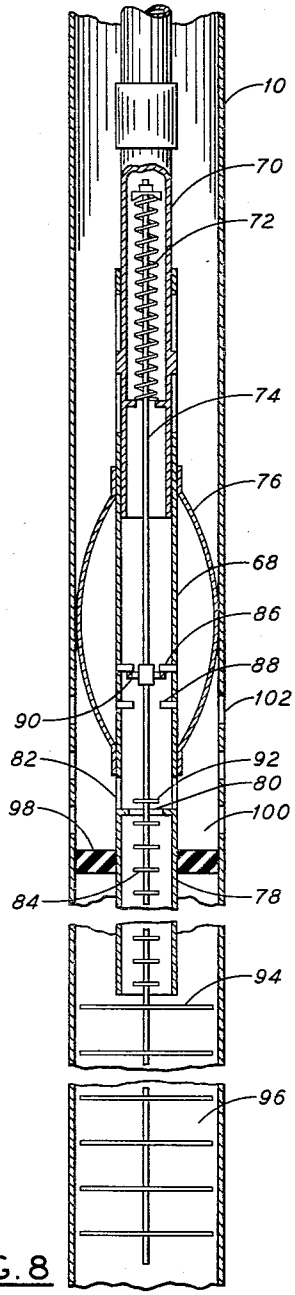


FIG. 8

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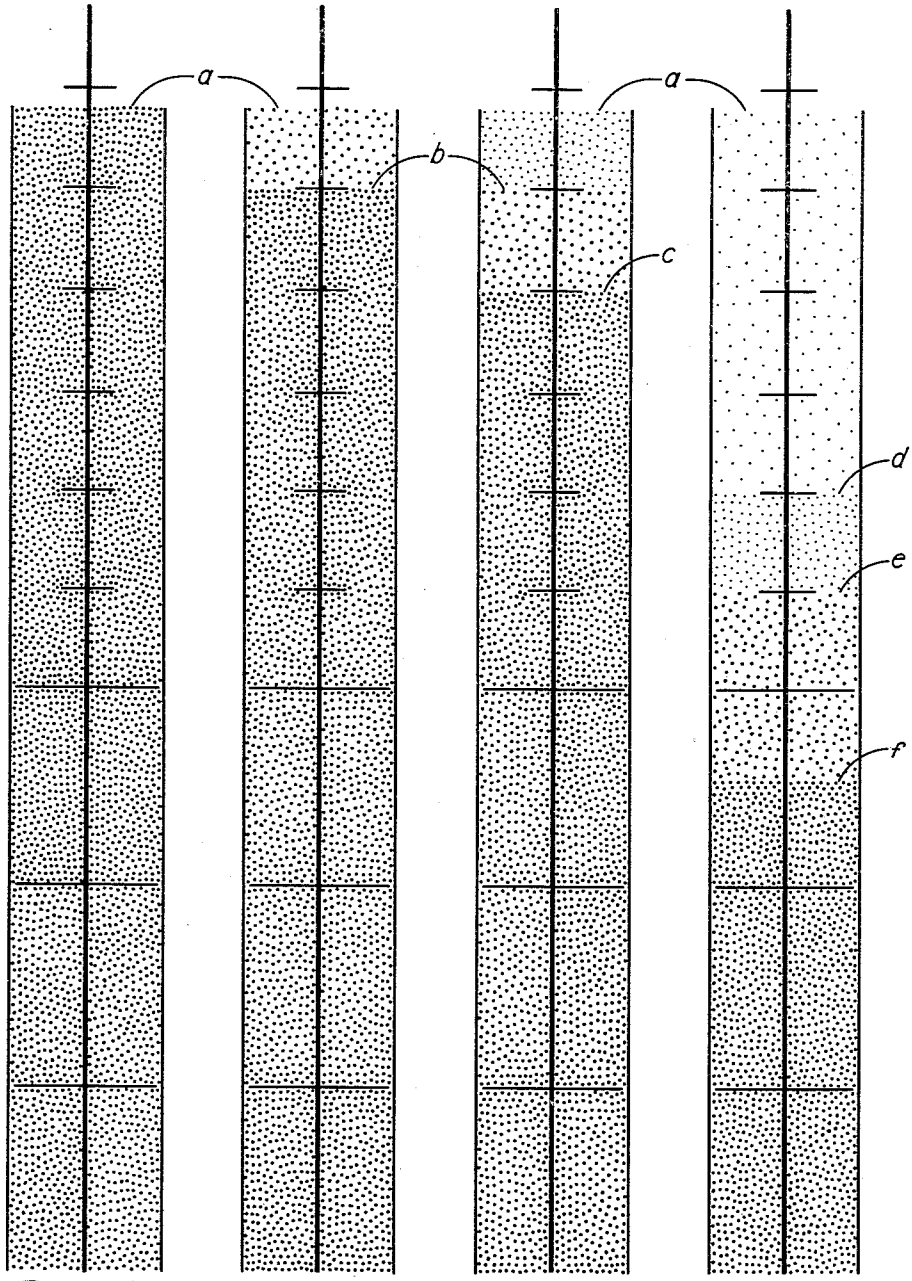


FIG. 2A FIG. 2B FIG. 2C FIG. 2D

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DIFFUSION APPARATUS

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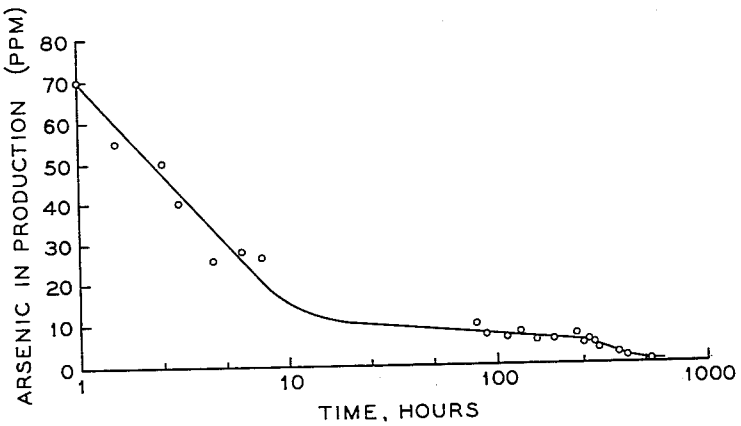


FIG. 3

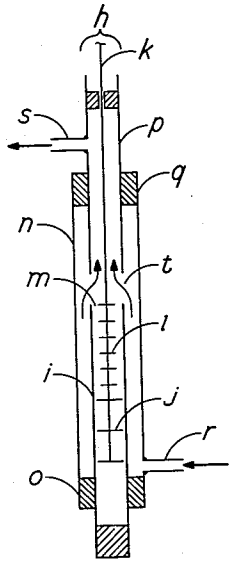


FIG. 3A

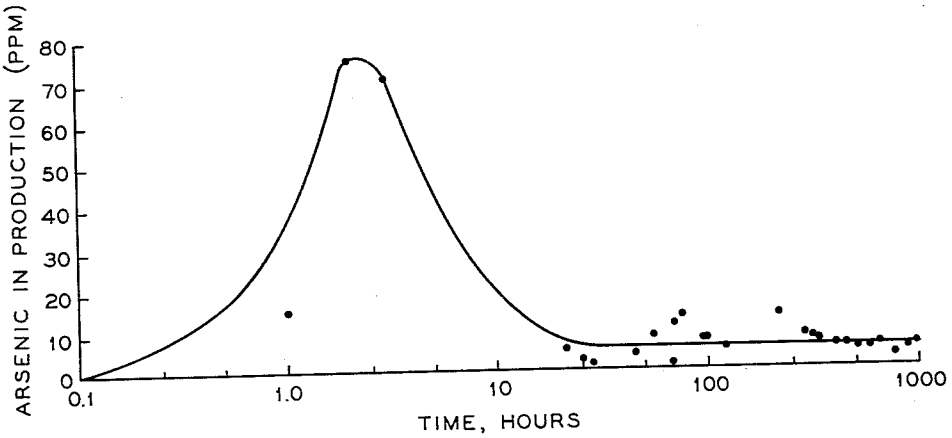


FIG. 6

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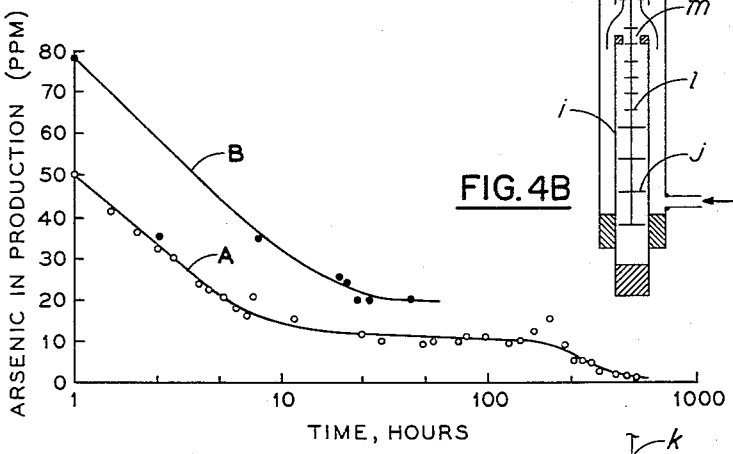


FIG. 4

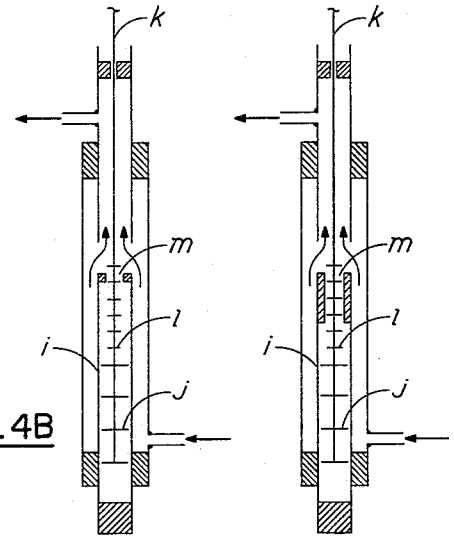


FIG. 4B

FIG. 4A

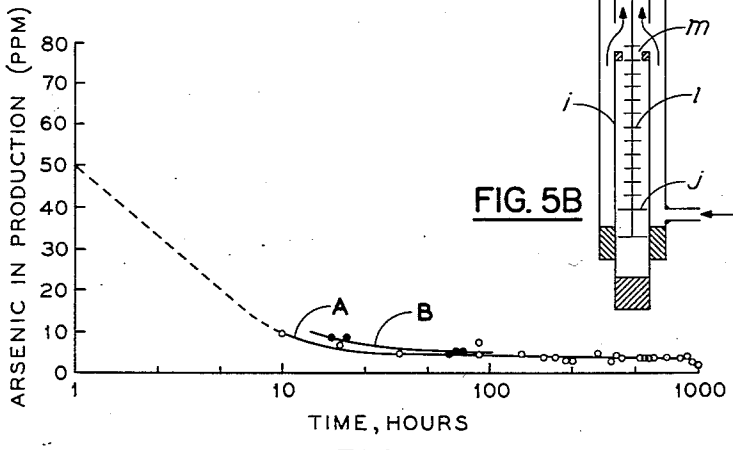


FIG. 5

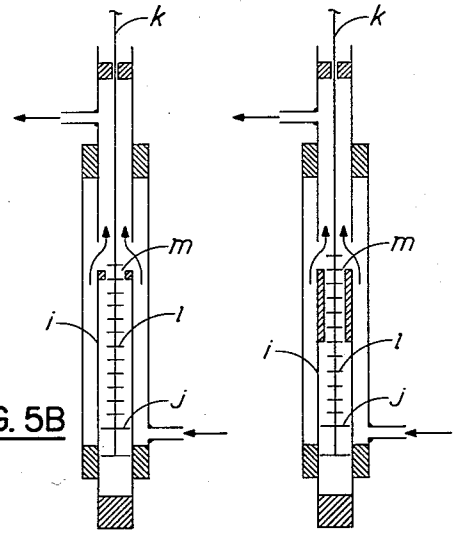


FIG. 5B

FIG. 5A

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United States Patent Office 2,993,542 Patented July 25, 1961

2,993,542

DIFFUSION APPARATUS

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Filed Mar. 31, 1958, Ser. No. 725,415
8 Claims. (Cl. 166—243)

This invention relates to a means for feeding an inhibiting agent into a body of a liquid which causes the corrosion of or deposits scale on the surfaces of apparatus with which it comes in contact. More particularly, this invention is directed to a device for diffusing a solution of corrosion or scale inhibitor into the fluids at the bottom of an oil well in a controlled manner and for a long period of time to provide protection of the well equipment from corrosion or scale formations.

The problem of protecting many forms of equipment, especially that made from ferrous metal, from attack by the fluid products contained in or flowing through them is, of course, a common one. Inhibitors placed in the product stream have been used for this purpose with varying success. One of the difficulties in providing adequate protection through the use of an inhibitor has been that of maintaining a significant concentration of it in the product stream during a prolonged period of operation of the equipment without requiring the continuing attention of an operator to replenish it. This problem is particularly aggravated in such environments as producing oil wells where the corrosive well brine enters and is entrained by the well equipment deep within the well bore. Such expedients as periodically treating the well with a sufficient excess of corrosion inhibitor to carry the inhibiting effect over the periods between treatments are in common field use. However, besides requiring the frequent attention of the operator, it is always doubtful in this method of operation whether the inhibitor is present for a practical period of time at a significant level of concentration to be effective at the bottom of the well where the apparatus is first exposed to contact with the corrosive fluids.

It has been proposed heretofore to provide apparatus for releasing inhibitor agents into process streams over a period of time to protect the related equipment without requiring the constant attention of an operator. Although in many such installations the feed apparatus can be placed in an advantageous position where it is accessible for adjustment, replenishment and repair, the desirability of having a feeding mechanism which will operate dependably for long periods of time without attention is apparent. Also, devices have been proposed for insertion into oil wells to release a corrosion or scale inhibitor into the well fluids over a period of time to circumvent the common practice of "slugging" or batch treating the well by the frequent introduction of inhibitors into the annulus or through the production tubing. The device which will be described subsequently to exemplify an embodiment of the present invention is related to the latter type of apparatus, but, as will become apparent from its description, differs in concept and function from those of the prior art. It can be applied also to installations other than oil wells where it is desired to feed an additive agent at a controlled level of concentration over a long period of time into a principal body of liquid.

The present device employs a reservoir of sufficient capacity to hold a supply of corrosion or scale retardant adequate for treating a process stream for a period of time extending preferably over a year or more. The treating agent is released from the reservoir by a mechanically actuated diffusion apparatus which is proportioned

and automatically operated to maintain a predetermined level of concentration of the agent in the product stream over this period. The diffusion apparatus comprises a series of baffle means fixed to a reciprocating rod which extends into the reservoir through an opening which also continuously exposes the reservoir to the fluids of the product stream. The reciprocating baffle means cause a diffusion of liquids between the reservoir and the product stream at a predetermined rate, so that the inhibiting agent will be fed into the product stream continuously at a predetermined level of concentration. The relative proportions of the reservoir opening, the construction of the baffle means, and the amplitude of their movement all contribute to the feed and control functions of the apparatus in a manner to be described subsequently.

It is an object of this invention to provide a novel means for continuously diffusing an agent into a principal body of fluid.

A further object of this invention is to provide a novel means for automatically dispensing an inhibiting agent at a desired level of concentration and over a prolonged period of time into a stream of potentially corrosive fluid to achieve continuous inhibition of deleterious reactions between the fluid and the apparatus with which it comes in contact.

Another object of this invention is to provide a device for diffusing a corrosion inhibitor into the fluids at the bottom of an oil well and which will operate automatically in accordance with the rate at which the fluids are withdrawn from the well to diffuse a sufficient amount of inhibitor to maintain the concentration of it in the well effluent at a desired level.

Still another object of this invention is to provide at the bottom of an oil well a positively actuated feeder for an inhibiting agent, which feeder has incorporated with it a reservoir of sufficient capacity to supply the inhibiting agent for dispersion into the well fluids for a period of many months and with means provided for replenishing the reservoir in place, so that the operation of the feeder may be continued for longer periods without withdrawing it from the well.

Other objects will become apparent as the description of the invention proceeds hereinafter. To present a clear teaching of the inventive concept, some exemplary embodiments of the invention will be described in the form of a device for diffusing a corrosion inhibitor into the fluids being pumped from an oil well. These exemplary embodiments are illustrated in the accompanying drawings, which form part of this specification.

In the drawings:

FIG. 1 represents in side elevation and partly in section a corrosion inhibitor feeder in accordance with this invention installed in an oil well, and shows the relationship of the parts in one position of operation.

FIGS. 2A to 2D inclusive are diagrammatic illustrations of the interaction of fluids within the reservoir of the feeder mechanism.

FIG. 3A illustrates schematically a modification of a feeder device, and FIG. 3 is a graph of its feeding action.

FIGS. 4A and 4B are schematic illustrations of two other modifications of feeder devices, and FIG. 4 shows corresponding graphs of their feeding action.

FIGS. 5A and 5B illustrate schematically two additional modifications of feeder devices, and FIG. 5 shows the corresponding graphs of their feeding action.

FIG. 6 represents the graph of the feeding action of a feeder device operating in a producing well.

FIGS. 7 and 8 represent in side elevation and partly in section other modifications of feeder devices made in accordance with this invention.

Referring now to FIG. 1 of the drawings, a feeder made

in accordance with this invention is illustrated as installed within the casing liner **10** of an oil well from which the well fluids are being removed by a pump. The pump, although not shown, may in this instance be any of the well-known types of reciprocating pumps in oil field use, and, as is common practice with these devices, the well fluids are drawn into the pump barrel **12** through the check valve **14** and thence pumped through production tubing to the surface.

In such installations a certain amount of reciprocating tubing stretch and relaxation accompanies the pump actions, and it varies from well to well, depending on such variables as the tubing size, sucker rod string design, pump plunger size, pump stroke length, pump depth and the density of the well fluids. Tubing stretch may amount to several feet, and numerous tables and nomographs have been devised to assist in determining this factor. In the present illustrative embodiment of the invention, the reciprocating tubing stretch is used as a source of power to actuate the diffuser mechanism. It will be apparent, however, that this is merely a convenient arrangement for use in a pumping oil well and that other actuating means may readily be used for the diffuser mechanism.

The exemplified feeder device comprises a hollow cylindrical structure **16**, the upper portion **18** of which is open and the lower portion **20** of which is closed at the bottom by a check valve **22** and plug member **24** to form a reservoir for the corrosion inhibitor. Two sets of centralizer springs **26** secured to the outer wall of structure **16** expand against the inner wall of liner **10** with sufficient pressure to hold the structure relatively stationary while the diffuser mechanism is actuated by the tubing stretch. However, these springs may slip along the wall of the liner when sufficient force is placed on the feeder device, permitting it to be inserted into operating position in the well casing and withdrawn therefrom.

The cylindrical upper portion of the feeder structure receives in telescopic relationship a cylindrical sleeve **28** which is connected at its upper end by a collar **30** to the lower end of the pump barrel. The interrelated parts are proportioned to permit the sleeve to slide into and out of the portion **18** as the production tubing stretches and relaxes while the pump is operating.

The upper portion of the feeder structure has formed through its walls a plurality of longitudinal slots **32** which receive in sliding relationship complementary projections **34** affixed to the telescoped sleeve. The top and bottom and walls **36** and **38**, respectively, of the slots form the limits of movement of the sleeve **28** relative to the body of the feeder. Preferably, for each particular installation the length of these slots is made greater than the amplitude of reciprocation of the production tubing to permit the sleeve to reciprocate a like amount without causing an abutment between the projections **34** and the end walls of the slots at each end of the travel.

The reciprocating motion of the sleeve **28** is transferred through a spring **40** to a rod **42** which is positioned along the longitudinal axis of the feeder structure. In this particular modification, a helical spring designed to act in compression is shown, although it is obvious that a spring acting in tension may be used. It surrounds the upper portion of the rod and is seated between circumferentially spaced projections **44** fixed to and extending radially inwardly from the inner wall of the sleeve and a spider **46** detachably secured to the upper end of the rod.

For reasons to be explained hereinafter, it will be desirable in most applications of this device to limit the travel of the rod **42** to an amplitude less than that of the tubing stretch, and stops are provided in the device for this purpose. Thus, with the construction described above, when the upper travel of the rod is stopped within the device the sleeve **28** may continue to move upwardly, since the spring **40** will compress to permit relative motion between the parts.

In the present modification of the device the upper boundary of reservoir **20** is defined by an annular projection **48** extending within the cylindrical structure **16**. Ports **50** are formed through the wall of the structure immediately above this projection to permit the entry of well fluids into the feeder. Subsequently, these fluids will be drawn through the sleeve **28** by the well pump and thence pumped through the production tubing to the surface. The central orifice **52** in the annular projection permits a continuous interchange between the well fluids and the solution of corrosion inhibitor in the reservoir. The apparatus of this invention includes a unique mechanism for controlling this interchange of fluids in a manner to feed out of the reservoir an amount of corrosion inhibitor necessary to maintain a predetermined level of concentration of it in the fluids being pumped from the well.

For purposes of description, the reservoir **20** may be divided into sections, a lower section **54** which will be called the mixing section and an upper section **56** which will be called the feeder section. The rod **42** passes through the orifice **52** and extends along the axis of the reservoir to a point proximate its bottom. A plurality of baffle means, such as circular, transverse plates, are fixed to the rod in spaced relationship and extend along it for a distance substantially coextensive with the length of the reservoir. These plates are employed to transmit energy from the rod to the body of fluids in the reservoir to cause a controlled diffusion of the fluids. It is readily apparent that other configurations of baffle means than the transversely extending plates shown may be used for this purpose. The construction and spacing of the baffle means will affect the characteristics of the corrosion inhibitor feeder in a manner to be explained hereinafter.

The diameters of the plates are less than the internal diameter of the reservoir to provide a radial space between their circumferences and the inner wall of the reservoir. The mixing portion of the reservoir has plates **58** which are only slightly smaller in diameter than the internal diameter of the reservoir. Stop members **60** and **61** affixed to the inner wall of the reservoir are placed between the two lowermost of these plates to limit amplitude of the travel of the rod **42** to this distance. This amplitude then determines and will be called the stroke length of the diffuser mechanism. In the modification being described, the stroke length is equal to approximately one-half the spacing of the mixing plates.

The feeder portion of the reservoir has plates **62** of appreciably smaller diameter spaced on the rod at intervals approximately one-half of the distance between the plates in the mixing portion, or one stroke length. The diameter of the plates in the feeder portion is less than the diameter of the orifice **52**, so that a feeder plate may pass through the orifice with a radial clearance. One of the feeder plates, preferably the uppermost one **64**, is positioned on the rod to pass upwardly and downwardly through the orifice as the rod reciprocates. This plate imparts energy to the interface between the well fluids and concentrated corrosion inhibitor at the opening of the orifice, and initiates the intermingling and diffusion of the fluids in the reservoir.

The interaction between the well fluids and the solution of corrosion inhibitor within the reservoir of the device over a period of time is illustrated diagrammatically in FIGS. 2A through 2D. To obtain this information, a feeder device was made with transparent parts to enable the mixing action of the fluids to be observed continuously. The details of construction and proportions of the various parts of this device will be described subsequently in connection with FIG. 3A. The reservoir was filled with a concentrated solution of corrosion inhibitor containing, in weight units, 15 parts water, 6 parts sodium hydroxide and 25 parts arsenous oxide. The apparatus was operated to simulate the flow conditions of a well making 100 barrels per day of brine.

FIG. 2A illustrates the condition of the feeder mechanism prior to the start of operation. As will be noted, an interface "*a*" occurs between the well fluids and the concentrated corrosion inhibitor at the topmost portion of the reservoir. A maximum concentration gradient exists at this interface.

After several hours' operation a second interface "*b*," FIG. 2B, is established within the reservoir at the level of the upper limit of travel of the second feeder plate. The concentration gradient at the interface "*a*" has been reduced somewhat by dilution with well fluids of the concentrated corrosion inhibitor below the interface. The inhibitor content in the effluent from the apparatus was measured by determining the concentration of arsenic in it and showed that the output of inhibitor from the feeder started at a high point of 70 parts per million arsenic in the effluent and continuously decreased with time, as indicated by the curve of FIG. 3. When the condition illustrated in FIG. 2B was established, the concentration of inhibitor in the effluent was still decreasing, but at a slower rate.

FIG. 2C indicates the conditions within the reservoir after several more hours of operation. It will be noted that the second interface "*b*" persists at the level of the upper limit of travel of the second plate and that a third interface "*c*" has been established at the level of the upper limit of travel of the third plate. The concentrations of corrosion inhibitor in the regions between interfaces have steadily decreased, and the concentration in the region between interfaces "*b*" and "*c*" is intermediate to that above and below this region. When this condition obtains, the concentration of inhibitor in the effluent has substantially leveled off, and the rates at which the corrosion inhibitor solution in the upper portion of the feeder section is being diluted by well fluids and concentrated by inhibitor fed upwardly by the apparatus are approaching equilibrium.

FIG. 2D shows the conditions in the feeder reservoir after approximately 24 hours of operation. During this time the concentration gradients migrate downwardly in the reservoir, and gradients "*d*" and "*e*" become established progressively at the lower plate levels in the feeder section of it. The concentration of inhibitor in the upper part of the feeder section between interfaces "*a*"—"*d*" has reached an equilibrium, and the device will feed out uniform quantities of inhibitor at substantially this concentration during its continuing operation.

It will be noted that a concentration gradient "*f*" has now become established in the mixing section of the reservoir between the two uppermost mixing plates. As the operation continues, other gradients become established successively below this gradient, and sufficient inhibitor solution is moved upwardly through the device to maintain the concentration in the feeder section at its equilibrium level. The output of the feeder device remains substantially constant until the reservoir nears depletion. With proper adjustment of plate size, plate spacing and stroke length, a relatively constant concentration of corrosion inhibitor can be maintained in the effluent until the reservoir is approximately 90% depleted.

The relationship between the plate spacings, plate diameters, diameter of the orifice, stroke length and stroke frequency are the principal factors which determine the rate of feed of corrosion inhibitor into the well fluids. Several different arrangements of these factors are illustrated diagrammatically in FIGS. 3 to 5, together with the result obtained. To assist the explanation of the comparative effects of varying the dimensions and components of the feeder mechanism, the same letters are used to designate corresponding parts in the various modifications.

As illustrated in FIG. 3A, a feeder mechanism "*h*" was made with a reservoir "*i*" having an internal diameter of 0.73". Three plates "*j*" of 0.64" diameter attached to rod "*k*" were placed in the mixing section of the reservoir and spaced 1.5" apart. In the feeder section were placed six plates "*l*" of 0.22" diameter spaced 0.75" apart. In this modification of the invention, no orifice plate was used at the upper portion of the reservoir, and the full internal diameter "*m*" of the top of the reservoir was the orifice. The stroke of the plate rod "*x*" was limited to 0.75".

The feeder was placed in a cylindrical housing "*n*" which was closed at its bottom around the reservoir by a fluid-tight seal "*o*", and at its top around the axially aligned tube "*p*" by a fluid-tight seal "*q*." A stream of liquid simulating an oil well brine was introduced into the lower portion of the housing through a conduit "*r*" and withdrawn by a pump through the conduit "*s*" communicating with tube "*p*." Thus the brine was constrained to flow upwardly around the outside of the reservoir and through the openings "*t*" into the tube "*p*" and thence to the pump. This arrangement simulates the fluid system for this feeder in a producing well. The reservoir was filled with an aqueous solution of arsenous corrosion inhibitor similar to that described heretofore, having a concentration of As_2O_3 of approximately 54 percent and a density of 2.0. The flow of brine through the housing was regulated to simulate the flow conditions of a well producing 100 barrels of brine per day, and the feeder mechanism was placed in operation at 20 strokes per minute by an auxiliary device which reciprocated the rod. Frequent determinations were made of the concentration of corrosion inhibitor in the effluent from the apparatus.

The curve in FIG. 3 represents the change in the concentration of inhibitor in the effluent plotted against a logarithmic time scale. It will be noted that the concentration of arsenic in the effluent stream was 70 p.p.m. at the start of the operation. This concentration fell off relatively rapidly and in approximately 20 hours was down to a level of 10 p.p.m. The concentration of the inhibitor tended to stabilize at this plateau, indicating that the corrosion inhibitor feeder had reached a stable condition of operation. The output of the feeder dropped slowly to 5 p.p.m. over a period of some 200 hours and then decreased more rapidly until the reservoir was exhausted.

The stabilized plateau corresponds to the desired operating level of the corrosion inhibitor feeder over a prolonged period. It will be appreciated that the length of time the feeder will operate at this level is dependent on the capacity of the reservoir. In the apparatus illustrated, the reservoir had a capacity for approximately several days' operation, and hence was exhausted relatively rapidly. In the devices made for oil field use the reservoir has sufficient capacity to operate for a year or more.

FIGS. 4 and 5 illustrate comparatively similar results obtained by maintaining certain relative proportions among the components of the feeder structure, even though the physical dimensions of the parts may be considerably different in various feeder mechanisms.

The corrosion inhibitor feeder illustrated in FIG. 4A has a reservoir "*i*" with an internal diameter of 0.73". Four plates "*j*" in the mixing portion of the reservoir have each a diameter of 0.64" and are spaced 1.5" apart. Six plates "*l*" in the feeder portion of the reservoir are 0.22" in diameter and spaced 0.75" apart. The stroke of the plate rod "*k*" is 0.75", and the rod is actuated at 20 strokes per minute. In this modification of the device, an orifice "*m*" 0.41" in diameter and 2.3" long was placed in the upper part of the reservoir, and the topmost feeder plate was positioned to sweep through the interface between the fluids at the top end of the orifice. The feeder mechanism was placed in a housing "*n*" through which brine was pumped in the manner and at the rate described heretofore.

Curve A of FIG. 4 also represents the concentration of inhibitor in the effluent plotted against a logarithmic time scale. It will be noted that the concentration was initially high and rapidly decreased while the feeder approached an equilibrium condition of operation. It be-

came stabilized at approximately 12 p.p.m. after 20 hours' operation, and during further prolonged operation dropped slowly to 10 p.p.m. until the time when the corrosion inhibitor in the reservoir was substantially depleted. The plateau at approximately 12 to 10 p.p.m. can be maintained for a longer period by increasing the capacity of the reservoir.

The device shown in FIG. 4B has, except for the orifice, a similar relationship between the components as that of FIG. 4A, but the physical dimensions of the parts are increased considerably. In this modification of the device, a reservoir "*i*" of 2.5" internal diameter was used, containing four plates "*j*" in the mixing portion of 1.93" diameter spaced 4" apart. The six plates "*l*" in the feeder portion are 0.7" in diameter and spaced 2" apart. The orifice "*m*" is 1.25" in diameter and has a length of 0.5". The stroke of the plate rod "*k*" is 2" and is actuated at 20 strokes per minute.

Curve B of FIG. 4 indicates the results obtained with this device. It will be noted that the concentration of the inhibitor in the effluent reached a plateau in about the same amount of time as required for the device illustrated in FIG. 4A, but with this arrangement, principally due to the different orifice structure, the plateau level was approximately 20 p.p.m.

The device illustrated in FIG. 5A has a reservoir "*i*" of 0.73" internal diameter in which there are two mixing plates "*j*" of 0.64" diameter spaced 1.5" apart and 12 feeder plates "*l*" of 0.22" diameter spaced 0.75" apart. The orifice "*m*" is 0.41" in diameter and 4" long. The plate rod "*k*" has a stroke length of 0.75" and a frequency of 20 strokes per minute.

Curve A of FIG. 5 indicates the control of the feed of corrosion inhibitor to the effluent stream obtained with this device. It will be noted that a plateau of approximately 3 p.p.m. concentration is reached after approximately 30 hours' operation and is maintained substantially at this level until the reservoir is depleted.

The device shown in FIG. 5B has a reservoir of 2.5" internal diameter containing two mixing plates of 1.9" diameter spaced 2" apart and twelve feeder plates of 0.7" diameter spaced 1" apart. The orifice is 1.25" in diameter and 0.5" long. The plate rod has a stroke of 1" and a frequency of 20 strokes per minute.

Curve B of FIG. 5 indicates the results obtained with this device. It will be noted that although the dimensions of device illustrated in FIG. 5B are considerably larger than those of the device illustrated in FIG. 5A, it will dispense the corrosion inhibitor at very close to the same rate and maintain the same level of concentration of the inhibitor in the effluent as did device illustrated in FIG. 5A.

A comparison of the devices illustrated in FIGS. 4A and 5A, which are similar in size, indicates that rate of feed is affected by the number of plates in the feeder section. The device of FIG. 4A, which has six plates in this section, releases approximately three times as much inhibitor as the device of 5A, which has 12 feeder plates. Further, a comparison of the devices of FIGS. 3A and 5A, which also are similar in size, indicates that the opening of the orifice at the top of the reservoir affects the rate of feed, and that the rate can be increased in the range of 25% to 50% by decreasing the opening.

A comparison of the similar-sized devices 4B and 5B indicates that by reducing the number of feeder plates and increasing the stroke length, the relationship of the plate spacing and stroke length being maintained constant, the rate of feed of the device can be increased by approximately a factor of five.

It has been determined that optimum control of the feeder output is achieved when the spacing of the plates of the feeder portion of the reservoir is substantially equal to the stroke length. However, good control can be maintained when the plate spacing in both the feeder and mixing sections is maintained between one and two times the stroke length. If the plates are spaced too far apart, the device becomes diffusion-limited; that is, the fluids will intermix only in accordance with what would be approximately their normal diffusion characteristics, and the rate of mixing or diffusion of the fluids in the reservoir will not be appreciably affected by the reciprocating plates. If the plates are spaced too closely together, their action obliterates the concentration gradients in the reservior, adequate control of the low rate of feed at which it is desired to release the corrosion inhibitor from the device is lost and the reservoir is then rapidly exhausted. It has been determined further that for any particular spacing of the feeder plates, if the stroke lenght is increased by a factor of two, the output of the feeder is increased by approximately a factor of 15.

The devices shown in FIGS. 4B and 5B have dimensions approximating those of a corrosion inhibitor feeder which may be used in a producing oil well, and the curves corresponding to these figures indicate the control which can be obtained with such devices of the level of concentration of a corrosion inhibitor in the well effluent.

A device comparable in construction to the modification shown in FIG. 1 of the drawings was installed in an oil well. This device has a cylindrical feeder structure of 3" internal diameter and an over-all length of 31 feet. The telescopic sleeve at the top of the feoeder has a travel of 6", and the travel of the plate rod is limited to 1". One hundred fifty-eight mixing plates 2¼" in diameter spaced 2" apart are placed in the mixing portion of the reservoir, and the feeder portion contains 5 plates 1 1/16" in diameter spaced 1" apart. An orifice 1½" in diameter and ¼" thick is placed at the opening of the reservoir. The top feeder plate is positioned on the plate rod to pass through the orifice. The plate rod terminates approximately 12" above the check valve in the bottom of the reservoir to provide space for the accumulation of sediments without blocking the reciprocating action of the rod.

The compression spring connecting the telescoping sleeve and the plate rod is designed to compress 6" under a load of 125 pounds. The centralizer springs are made with sufficient strength to anchor the feeder mechanism in the well liner against this load, but permit the feeder mechanism to be displaced when the load substantially exceeds this amount.

The capacity of the reservoir, when filled with a concentrated solution of corrosion inhibitor containing approximately 54 percent of As_2O_3, is designed to supply sufficient inhibitor to treat the well fluids at a concentration level of 5 to 10 p.p.m. of arsenic for a period of 300 to 400 days in a well producing 100 barrels of brine per day. The reservoir is filled with the concentrated corrosion inhibitor by removing the protective plug at its bottom and forcing the inhibitor through the check valve with a pump until it reaches the level of the orifice, and the filled condition can be observed through the ports above the orifice. Alternatively, of course, the reservoir may be filled by pumping a measured amount of corrosion inhibitor into it. When the reservoir is filled, the protective plug is replaced and the feeder device attached to the end of the pump barrel, after which it is lowered into the hole while the well pump is lowered into place. Sufficient force is placed on the production tubing to cause the centralizer springs to slip downwardly along the well liner until the feeder mechanism is located approximately in its operating position.

When the well pump is placed in operation, the initial tubing stretch carries the telescoping sleeve of the feeder lower into the well bore, and the lugs on the sleeve contact the lower ends of the slots on the top portion of the feeder structure. This forces the device further into the well bore until it is positioned at the lowermost point of travel of tubing stretch. At this time the upper stroke-

limiting plate in the mixing section of the reservoir contacts its complementary stop, and hence the plate rod is at the bottom of its stroke.

When the production tubing relaxes from its position of maximum stretch, the telescoping sleeve is drawn upwardly with it, and the motion of the sleeve is transmitted through the compression spring to the plate rod. The travel of the rod continues upwardly until the lower stroke-limiting plate in the mixing section of the reservoir contacts its complementary stop. Subsequently, the sleeve may continue to travel upwardly, but the motion of it is absorbed in the spring while the plate rod remains in its upstroke position. Thus, while the production tubing reciprocates under pump action, the plate rod also will reciprocate, but its travel is limited to the stroke length built into the device.

The operation of the diffuser mechanism of the corrosion inhibitor feeder continues as long as the well pump is operating. When the reservoir is exhausted, the device is withdrawn from the well at the same time the production tubing and well pump are withdrawn. When it is on the surface, the protective plug is removed from the bottom of the device, and the check valve is displaced by a rod to permit the fluids in the reservoir to be drained from it. These fluids will, of course, be primarily the well fluids which have displaced the concentrated corrosion inhibitor during the feeder action. The device may now be refilled with concentrated corrosion inhibitor, the protective plug replaced, and it is ready to be attached again to the pump barrel and lowered into the well for continued operation.

The corrosion inhibitor feeder described immediately above was placed at a depth of 3400 feet in a pumping well which was producing 100 barrels of brine and 15 barrels of oil a day. The pump reciprocated at 18 strokes per minute. FIG. 6 is a graphic representation of the variations in concentration of the corrosion inhibitor in the well effluent during approximately a thousand hours' operation of the device. It will be noted that the corrosion inhibitor concentration was built up quickly in the well fluids and within a period of a few hours had reached a peak of approximately 75 p.p.m. arsenic concentration.

It will be clear from the explanation of the operation of the device that this build-up occurred during the initial phases of operation while the concentration gradients were being stabilized in the feeder section of the reservoir. Subsequently, the concentration of inhibitor in the well fluids dropped off rapidly, and after approximately 50 hours' operation it reached a plateau of approximately 6 p.p.m.

It may be noted that the initial high concentration of corrosion inhibitor in the well fluids is advantageous in producing a protective coating on the surfaces of the well apparatus which will provide a residual protection during any periods when the concentration of inhibitor falls below the optimum level, much in the manner achieved by periodically batch treating the well with corrosion inhibitor. As has been noted heretofore, this particular device has a reservoir supply of concentrated corrosion inhibitor sufficient to maintain a concentration level of 5 to 10 p.p.m. in the well fluids for a period of 300 to 400 days.

Another modification of a corrosion inhibitor feeder made in accordance with this invention is shown in FIG. 7. This device is similar to that of FIG. 1 with respect to the relative size and locations of the various elements with the exceptions detailed hereinafter, and the same reference numerals are used for corresponding parts. It will be noted that, whereas FIG. 1 illustrates the relative positions of the parts when the plate rod is at the bottom of its stroke, FIG. 7 illustrates their relative positions at the top of its stroke. The two figures indicate the travel of the topmost plate **64** of the feeder section of the mechanism through the interface at the orifice **52** during a cycle of operation.

The modification of FIG. 7 differs from that of FIG. 1 in that the protective plug **24** and check valve **22** have been eliminated from the bottom of the feeder mechanism, leaving the bottom of reservoir **20** open. This provides a means for replenishing the depleted feeder with concentrated corrosion inhibitor without withdrawing the device from the well bore. To accomplish this, concentrated corrosion inhibitor is pumped down the annulus **66** between the production tubing **12** and the well liner **10** into the bottom of the well bore. The greater density of the concentrated corrosion inhibitor causes it to displace the well fluids, enabling a measured amount of the concentrated corrosion inhibitor to be introduced itno the annulus to displace the well fluids at the bottom of the well bore and within the reservoir **20** up to approximately the level of the feeder orifice **48**.

It will be appreciated that with this modification the significantly increased effective reservoir for concentrated corrosion inhibitor enables a supply to be placed in the well bore to last a much longer time than the 300 to 400 days for which the modification shown in FIG. 1 is designed.

In installations where this modification is used, it is desirable to have the perforations **67** in the well liner through which the well fluids flow into the well bore placed at a level above the open bottom of the feeder reservoir. This prevents an uncontrolled mixing of the well fluids with the reservoir supply of concentrated corrosion inhibitor and enables the device to maintain the designed level of inhibitor in the effluent.

Another modification of a device in accordance with this invention is shown in FIG. 8. This modification employs the bottom portion of the lined well bore as the principal reservoir for the concentrated corrosion inhibitor. In this device a cylindrical structure **68** contains the telescoping sleeve **70** and the compression spring **72** which actuates the plate rod **74** in a manner similar to that described heretofore with respect to other modifications. Centralizer springs **76** are attached to the outer surface of structure **68** to hold it in position in the well liner in a manner similar to that previously described. The cylindrical structure **68** extends downwardly in the projection **78** which forms the feeder section of the device. An orifice **80** defines the upper limit of this feeder section and the ports **82** immediately above the orifice admit the well fluids into the device.

In this modification the plate rod has a stroke of approximately equal to the distance between the feeder plates **84** and the limits of the stroke are set by the stops **86** and **88** projecting from the inner wall of the structure and engaging the spider **90** affixed to the plate rod. The uppermost feeder plate **92** is positioned on the rod to pass through the orifice, and hence through the interface between the well fluids and the concentrated corrosion inhibitor, as the plate rod reciprocates. The mixing plates **94** have a diameter approaching that of the inner wall of the casing liner **10**, which now defines the wall of the reservoir **96** for the mixing section of the device. These plates are spaced approximately twice the distance of the feeder plates, or approximately twice the stroke length of the plate rod.

Before this device is installed in an oil well, preferably a measured amount of concentrated corrosion inhibitor of greater density than the well fluids is introduced into the well bore to displace the well fluids at the bottom and rise to a level approaching the position the orifice **80** will assume when the device is installed in operating position. The plate rod **74** is made long enough to extend approximately to the bottom of the well bore or to a packer or cement plug which may be set below the position to be occupied by the feeder mechanism to form the lower limit of the mixing section **96** of the reservoir. In some installations it may be desirable to set a packer

98 in the annulus 100 between the extension 78 and the casing liner to prevent well fluids which enter the well bore through perforations 102 in the casing liner 10 from mixing with the concentrated corrosion inhibitor prior to the time these fluids are mixed and diffused together under controlled conditions in the mixing and feeder sections of the device. However, ordinarily the difference in density between the well fluids and concentrated solution of corrosion inhibitor will maintain the desired separation of these fluids in the annulus.

The operation of this modification is similar to that of the modifications described heretofore. However, by expanding the reservoir to the diameter of the well bore, it is possible to make available an increased amount of concentrated corrosion inhibitor and hence extend the period during which the device can be operated without being replenished.

The various devices described heretofore are exemplary embodiments of diffusion apparatus made in accordance with this invention. They provide means for feeding a corrosion inhibitor into a flowing body of potentially corrosive fluids at a predetermined rate to maintain the concentration of inhibitor in the fluids at the optimum level desired for preventing the corrosion of the apparatus with which the fluids come in contact. It will be obvious that the function of the apparatus of this invention is not limited to feeding corrosion inhibitors but it can be applied to feeding or diffusing controlled amounts of an agent into a principal body of fluid automatically in a continuous manner over a long period of time. It will be appreciated also that many modifications of this apparatus can be made without departing from the inventive concept herein set forth, and it is intended to include all modifications within the scope of the appended claims.

I claim:

1. A device for dispensing a solution of corrosion inhibitor into a body of corrosive fluid comprising a reservoir for said corrosion inhibitor, said reservoir having an opening in the top thereof permitting continuous interchange between the corrosion inhibitor in said reservoir and said corrosive fluid, a longitudinal element extending through said opening and into said reservoir, a plurality of plates affixed to said longitudinal element in spaced-apart relationship and disposed within said reservoir, said plates projecting transversely of the axis of said longitudinal element a distance less than the internal transverse distance across said reservoir to provide radial clearance between the peripheral edge of said plates and the internal walls of said reservoir, means for reciprocating said longitudinal element axially relative to said reservoir to move said plates through the liquid in said reservoir, and means to position at least one of said plates to move inwardly and outwardly through said opening between a position within said reservoir and a position outside of said reservoir as said longitudinal element is reciprocated.

2. Apparatus for dispensing a solution of corrosion inhibitor into the fluids being produced from an oil well comprising a vertically elongated reservoir containing said corrosion inhibitor and positioned adjacent the bottom of said well, an opening in the top portion of said reservoir for continuous access of said well fluids thereto and egress of said corrosion inhibitor therefrom, a plurality of spaced-apart baffle means positioned within and along the longitudinal axis of said reservoir and fixedly mounted on support means reciprocally movable parallel to the longitudinal axis of said reservoir, and means for reciprocating said support means relative to said reservoir to reciprocate said baffle means toward and away from said opening.

3. Apparatus for releasing a corrosion inhibitor into well fluids adjacent the bottom of a well from which well fluids are being pumped by a reciprocating pump assembly inserted into the well comprising a reservoir for said corrosion inhibitor adapted to be positioned in said well below said pump assembly, means for holding said reservoir stationary in said well, a rod extending into said reservoir through an opening in the top portion thereof, means for connecting said rod to a reciprocating portion of said pump assembly to actuate said rod in vertically reciprocal motion relative to said reservoir when the reciprocating pump is actuated, a first plurality of baffle plates affixed to said rod and positioned within a lower portion of said reservoir, a second plurality of baffle plates affixed to said rod and positioned within an upper portion of said reservoir, means for positioning the topmost one of said second plurality of baffle plates for movement into and out of the said opening as said rod reciprocates, and means for directing said well fluids to said opening to entrain corrosion inhibitor released from the said apparatus.

4. A means for automatically diffusing a controlled amount of corrosion inhibitor over a prolonged period of time into the well fluids of a producing oil well comprising an elongated reservoir for said corrosion inhibitor positioned in said well substantially in axial alignment therewith and having a closed bottom end and an open top end, means for maintaining said reservoir stationary in position in the well bore, means for directing said well fluids to the said open top end of said reservoir, a rod extending into said reservoir through the said open top end and substantially in axial alignment with the vertical axis of said reservoir, a first plurality of plates affixed to said rod in vertically spaced relationship and extending transversely therefrom and positioned within a lower portion of said reservoir, said plates having a transverse dimension which provides a clearance between their peripheral edges and the inner walls of said reservoir to permit said plates to move relative to said reservoir without contacting the inner walls thereof, a second plurality of plates affixed to said rod in vertically spaced relationship and extending transversely therefrom and positioned within an upper portion of said reservoir contiguous to and in open communication with said lower portion, said second plurality of plates having a smaller transverse dimension than the plates of said first plurality, and means for reciprocating said rod in an axial direction to reciprocate said plates relative to said reservoir while said well fluids are being produced from said well to diffuse said corrosion inhibitor into said well fluids.

5. A diffusing means in accordance with claim 4 wherein the said oil well is lined with casing and said reservoir is formed in part by a portion of said casing.

6. A diffusing means in accordance with claim 4 wherein the opening at the top end of said reservoir is an orifice with an internal diameter smaller than the internal transverse dimension of the upper portion of said reservoir and the transverse dimension of the plates of the said second plurality is smaller than the internal diameter of said orifice.

7. A diffusing means in accordance with claim 4 wherein the topmost plate of said second plurality of plates is positioned on said rod to move into and out of the said open top end of said reservoir as said plates are reciprocated.

8. Apparatus for diffusing an agent in solution into a body of a separate liquid comprising a reservoir for said agent in solution, an opening at the top of said reservoir forming an orifice through which the interior of said reservoir is open to a separate liquid outside of said reservoir, a rod projecting into said reservoir through said orifice and extending to the lower portion of said reservoir, means to reciprocate said rod longitudinally relative to said reservoir, means to limit the stroke of the reciprocating rod to a predetermined repetitively uniform length, a plurality of mixing baffle means extending transversely from and affixed to said rod in spaced-apart relationship to each other at respective intervals in the range of substantially from one to two stroke lengths of said rod and located on said rod in the lower portion of said reservoir, a plurality of feeder baffle means extend-

ing transversely from and affixed to said rod in spaced-apart relationship to each other at respective intervals of approximately one stroke length of said rod and located on said rod in the upper portion of said reservoir, and at least one of said feeder baffle means positioned on said rod to reciprocate inwardly and outwardly of said reservoir through said orifice as said rod is reciprocated relative to said reservoir.

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